

Evidence for $B_s^0 \rightarrow D_s^{()} D_s^{(*)}$
and a Measurement of $\Delta\Gamma_s^{CP}$*

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(01/20/09)*

Introduction

Tevatron & DØ Detector

Analysis Procedure

Sampling

2D Likelihood Fitting

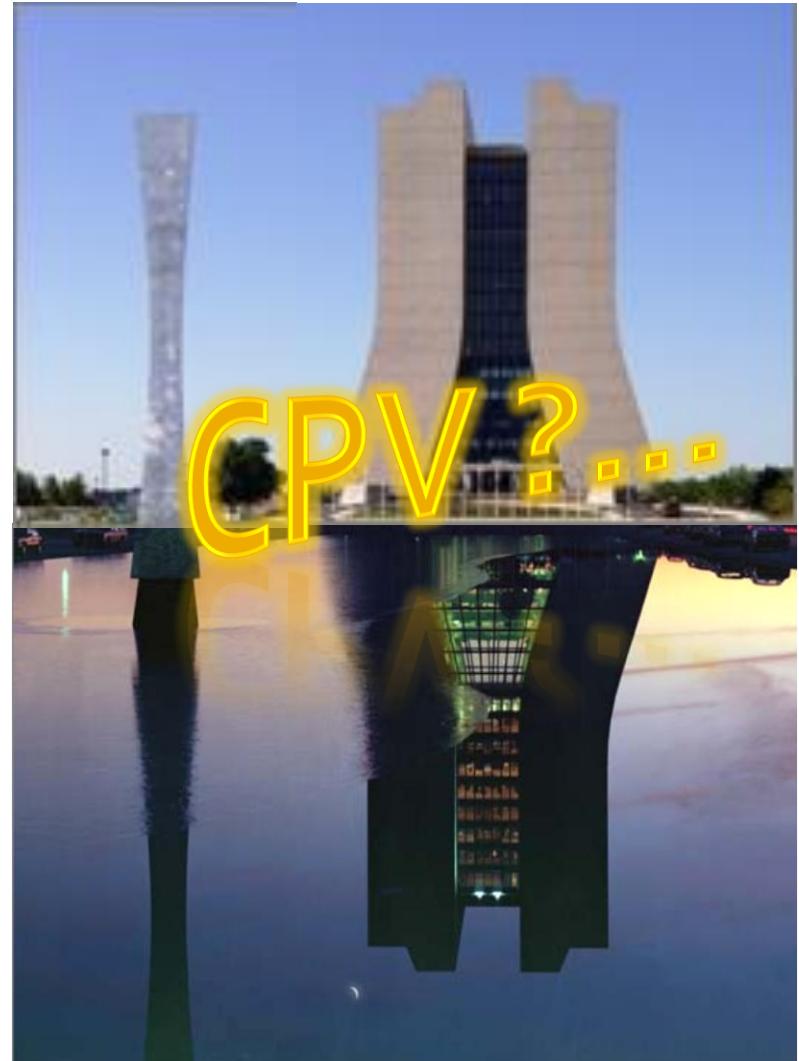
Sample Composition

Normalization

Single Muon Trigger Efficiency

Systematic Uncertainties

Result & Conclusion





Introduction





B_s^0 Meson



B mesons have offered direct ways to determine the phase structure of the CKM matrix for verification of the SM, and could be the key to understanding one of the fundamental mysteries of physics:

Dominance of matter in our present universe

Scientists conducting studies of CP (charge-parity) violation in neutral particle systems (K , B , ν , ...) have shed light on such imbalance

CPV in the B_s system is a prime candidate for the discovery of non-standard physics:

CPV in the SM ~ zero (CKM) → observation = NP

Decays of B_s mesons to CP eigenstates could provide further information on the matter-antimatter asymmetry





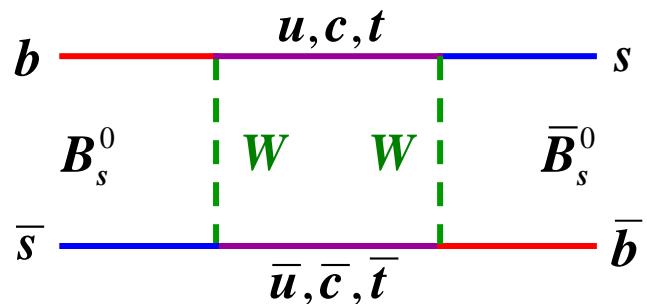
B_s^0 Meson



$$i \frac{d}{dt} \begin{pmatrix} |B_s^0(t)\rangle \\ |\bar{B}_s^0(t)\rangle \end{pmatrix} = \left(\textcolor{red}{M} - i \frac{\Gamma}{2} \right) \begin{pmatrix} |B_s^0(t)\rangle \\ |\bar{B}_s^0(t)\rangle \end{pmatrix}$$

M : mass matrix, Γ : decay matrix

$M_{12}=M_{21}^*$, $\Gamma_{12}=\Gamma_{21}^* \rightarrow$ Mixing



Mass / CP eigenstates

$$\text{Mass : } \begin{cases} |B_L\rangle = p|B_s^0\rangle + q|\bar{B}_s^0\rangle \\ |B_H\rangle = p|B_s^0\rangle - q|\bar{B}_s^0\rangle \end{cases}, \quad p^2 + q^2 = 1$$

$$\text{CP : } \begin{cases} |B^{even}\rangle = \frac{1}{\sqrt{2}}|B_s^0\rangle - \frac{1}{\sqrt{2}}|\bar{B}_s^0\rangle \\ |B^{odd}\rangle = \frac{1}{\sqrt{2}}|B_s^0\rangle + \frac{1}{\sqrt{2}}|\bar{B}_s^0\rangle \end{cases}$$

$$\Delta m_s = M_H - M_L \simeq 2|M_{12}|$$

$$\Delta \Gamma_s = \Gamma_L - \Gamma_H$$

$$\Delta \Gamma_s^{CP} (\equiv 2|\Gamma_{12}|) = \Gamma_s^{even} - \Gamma_s^{odd}$$

$$\Rightarrow \Delta \Gamma_s = \Delta \Gamma_s^{CP} \cos \phi_s \quad (\text{New Physics})$$

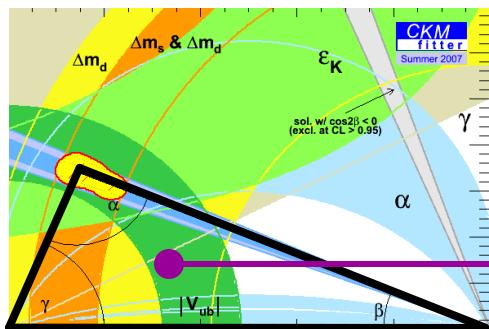
$$\phi_s = \arg \left(\frac{M_{12}}{\Gamma_{12}} \right) : CPV \text{ mixing phase}$$



CKM Matrix:

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1 & \lambda & \lambda^3 \\ \lambda & 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & 1 \end{pmatrix}$$

Unitary Triangle:



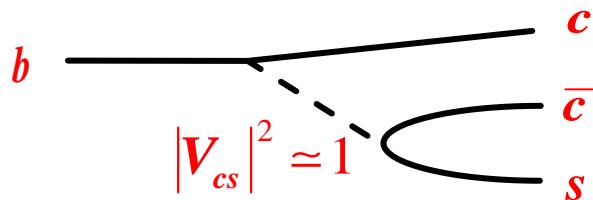
proportional to level of CPV

In SM, CP asymmetry vanishes

$$\beta_s \equiv \arg \left(-\frac{V_{ts} V_{tb}^*}{V_{cs} V_{cb}^*} \right)$$

- CPV in B_s^0 mixing ~ 0

$|\Gamma_{12}| (\approx \Delta\Gamma_s^{CP})$ is dominated through $b \rightarrow c\bar{c}s$ quark transition



- Ex) $B_s \rightarrow D_s^+ D_s^-$, $B_s \rightarrow J/\psi \varphi$

- coupling is non-negligible → $\Delta\Gamma_s^{CP}$ could be sizable

- CKM-favored tree-level decays → $\Delta\Gamma_s^{CP}$ is insensitive to NP
 $\Delta\Gamma_s^{CP} \approx \Delta\Gamma_s^{SM}$

$\Delta\Gamma_s = \Delta\Gamma_s^{CP} \cos\varphi_s$: Any deviation of φ_s from zero → new sources





For a single final state f :

$$Br(B_s^0 \rightarrow f) + Br(B_s^0 \rightarrow \bar{f})$$

$$= \Gamma(B_s^{even}) \left(\frac{1+\cos\phi_s}{2\Gamma_L} + \frac{1-\cos\phi_s}{2\Gamma_H} \right) + \Gamma(B_s^{odd}) \left(\frac{1-\cos\phi_s}{2\Gamma_L} + \frac{1+\cos\phi_s}{2\Gamma_H} \right)$$

$$\Rightarrow 2Br(B_s^0 \rightarrow f) = \Delta\Gamma_f^{CP} \left(\frac{\frac{1}{1-2x_f} + \cos\phi_s}{2\Gamma_L} + \frac{\frac{1}{1-2x_f} - \cos\phi_s}{2\Gamma_H} \right)$$

$$x_f = CP\text{-odd fraction} : \frac{\Gamma(B_s^{odd})}{\Gamma(B_s^{even})} \equiv \frac{x_f}{1-x_f}$$

For B_s^0 system:

- sum over all final states through $b \rightarrow c\bar{c}s$ transition

$$\Delta\Gamma_s^{CP} = \sum_{\substack{f \in \\ b \rightarrow c\bar{c}s}} \left[2Br(B_s^0 \rightarrow f) \cdot \left(\frac{\frac{1}{1-2x_f} + \cos\phi_s}{2\Gamma_L} + \frac{\frac{1}{1-2x_f} - \cos\phi_s}{2\Gamma_H} \right)^{-1} \right]$$

- theoretical uncertainty : $b \rightarrow u\bar{u}s$ ($\sim 3\text{-}5\%$) (Phys. Rev. D 63, 114015 (2001))

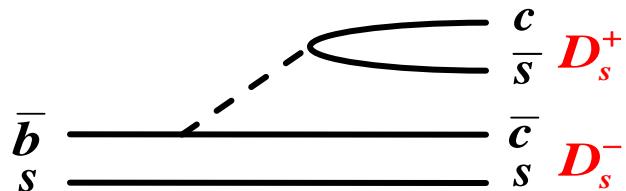


i) In the Shifman-Voloshin (SV) limit ($m_b - 2m_c \rightarrow 0$) with $N_c \rightarrow \infty$

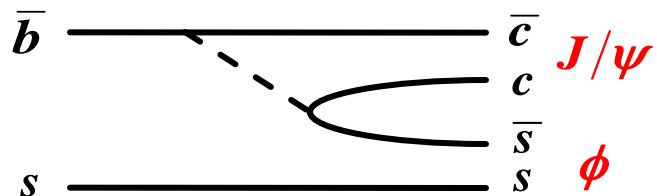
- multi-particle final states vanish (Sov. J. Nucl. Phys. 47, 511 (1988))

- effective color factor suppresses class II spectator decays ($\sim 1/N_c$)

(Phys. Lett. B 316, 567 (1993))



class I (color-allowed)



class II (color-suppressed)

- $\Delta\Gamma_s^{CP}$ is saturated by $\Gamma(B_s \rightarrow D_s^{(*)} D_s^{(*)})$

$$2Br(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}) \simeq \Delta\Gamma_s^{CP} \left(\frac{\frac{1}{1-2x_f} + \cos\phi_s}{2\Gamma_L} + \frac{\frac{1}{1-2x_f} - \cos\phi_s}{2\Gamma_H} \right)$$

- theoretical uncertainty : $\sim 0.01/0.15$ (Nucl. Phys. B 374, 263(1992))



Theoretical Assumptions



ii) In the heavy quark (HQ) limit ($m_c \rightarrow \infty$) (Phys. Lett. B 316, 567 (1993))

- D_s and D_s^* become degenerate
- amplitude of CP-odd component vanishes
- $D_s^{(*)} D_s^{(*)}$ final state becomes CP-even: $x_f = 0$ ($D_s^{(*)}$: D_s or D_s^*)

$$2Br(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}) \simeq \Delta\Gamma_s^{CP} \left(\frac{1 + \cos\phi_s}{2\Gamma_L} + \frac{1 - \cos\phi_s}{2\Gamma_H} \right)$$

- polarization study to disentangle CP structure

iii) In the SM ($\phi_s = 0$)

$$\frac{\Delta\Gamma_s^{SM}}{\Gamma_s} \simeq \frac{2Br(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)})}{1 - Br(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)})}$$

$$\Delta\Gamma_s = \Gamma_L - \Gamma_H, \quad \Gamma_s = \frac{\Gamma_L + \Gamma_H}{2}$$
$$\Delta\Gamma_s = \Delta\Gamma_s^{CP} \cos\phi_s$$

Lifetime information from BRs without lifetime fits !

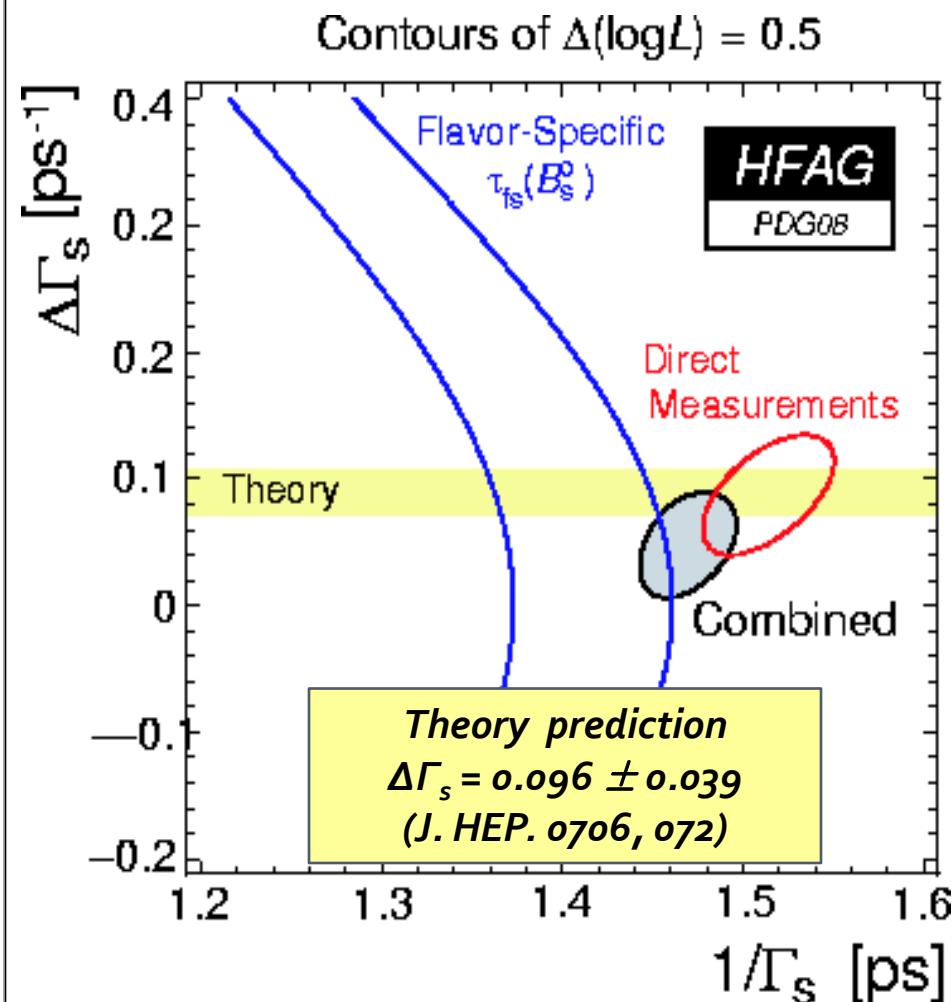


Flavor-Specific:

- $B_s^0 \rightarrow D_s^{(*)} \mu \nu$
- lifetime measurement
- 50% CP-even / 50% CP-odd

Direct Measurements:

- $B_s^0 \rightarrow J/\Psi \varphi$ ($D\bar{\theta}$ & CDF)
- angular analysis: $\Delta\Gamma_s$ & φ_s



Flavor-Specific:

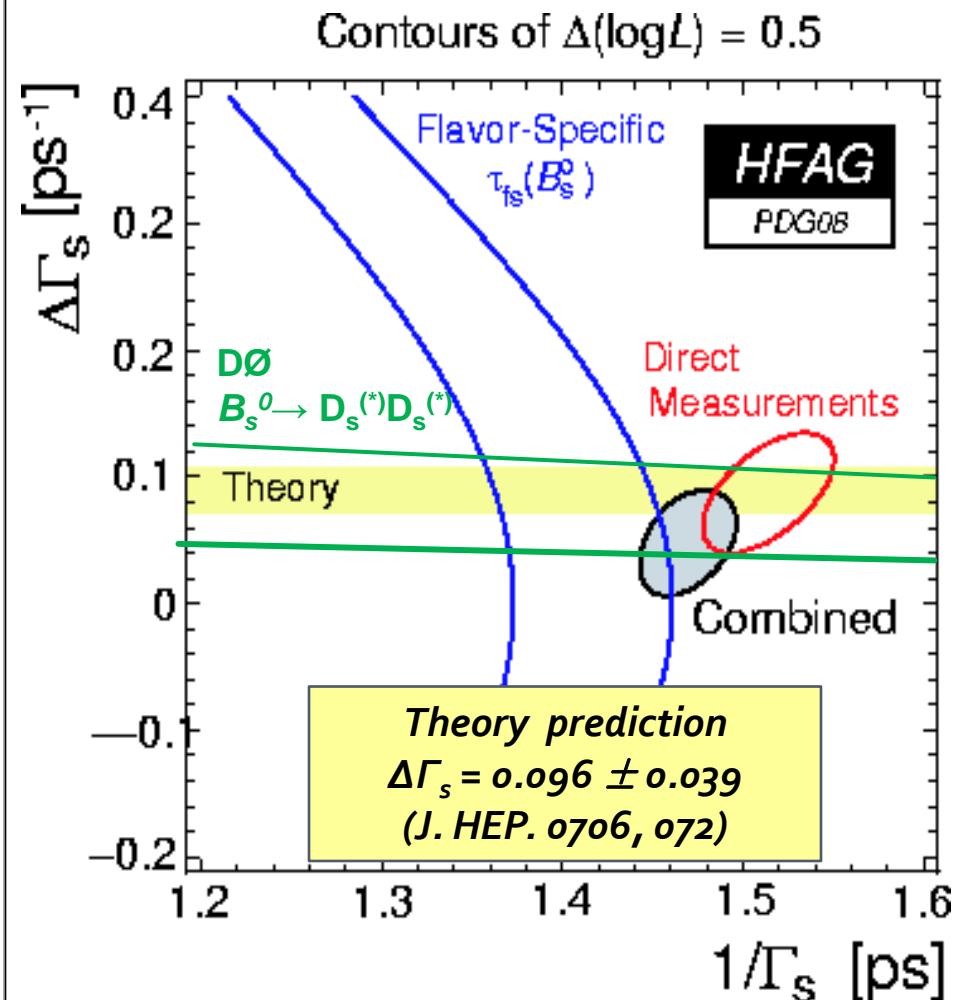
- $B_s^0 \rightarrow D_s^{(*)} \mu\nu$
- lifetime measurement
- 50% CP-even / 50% CP-odd

$B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}$:

- theory based analysis: CP-even
- consistent with theory
- compatible error band
- untagged: efficiency, purity, acceptance
- simple measurement

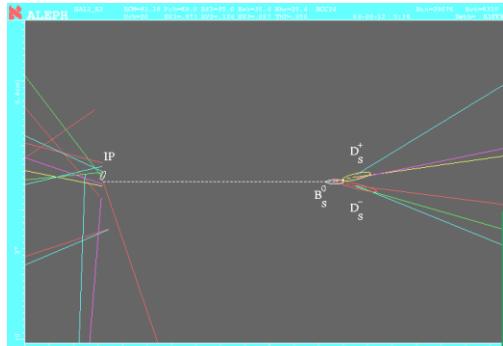
Direct Measurements:

- $B_s^0 \rightarrow J/\Psi \varphi$ (DØ & CDF)
- angular analysis: $\Delta\Gamma_s$ & φ_s



History of $B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}$

ALEPH (2000) - $\varphi\varphi$ correlation in Z decays



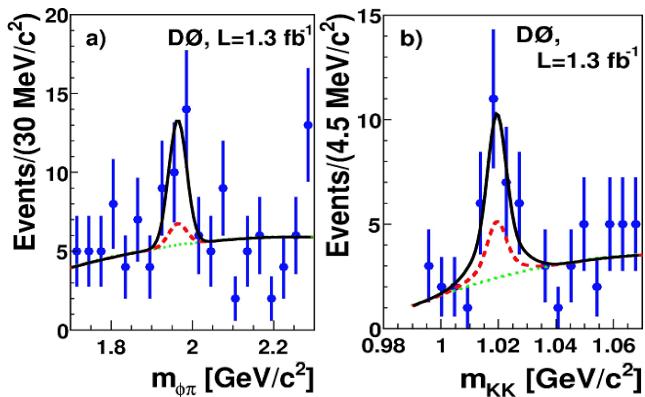
$$N = 18.5 \pm 6.7$$

$$Br = 0.077 \pm 0.034^{+0.038}_{-0.026}$$

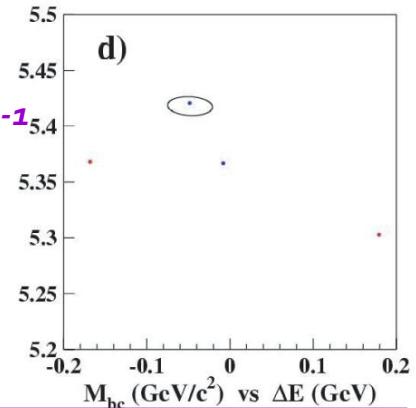
*DØ (2007) – 1.3 fb^{-1}
 $D_s D_s$ correlation*

$$N = 13.4^{+6.6}_{-6.0}$$

$$Br = 0.039^{+0.019+0.016}_{-0.017-0.015}$$



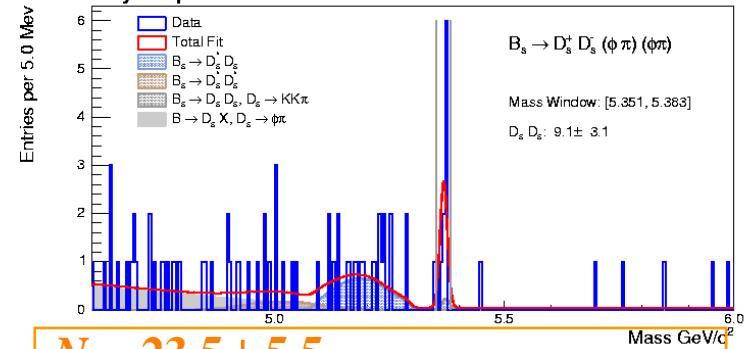
*Belle (2006) – 1.86 fb^{-1}
at Y(5S) resonance*



$$Br(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}) < 27.3\%$$

CDF (2006) – 355 pb^{-1} first hadronic

CDF Preliminary 355 pb^{-1}



$$N = 23.5 \pm 5.5$$

$$Br(B_s^0 \rightarrow D_s^+ D_s^-) / Br(B^0 \rightarrow D_s^+ D^-)$$

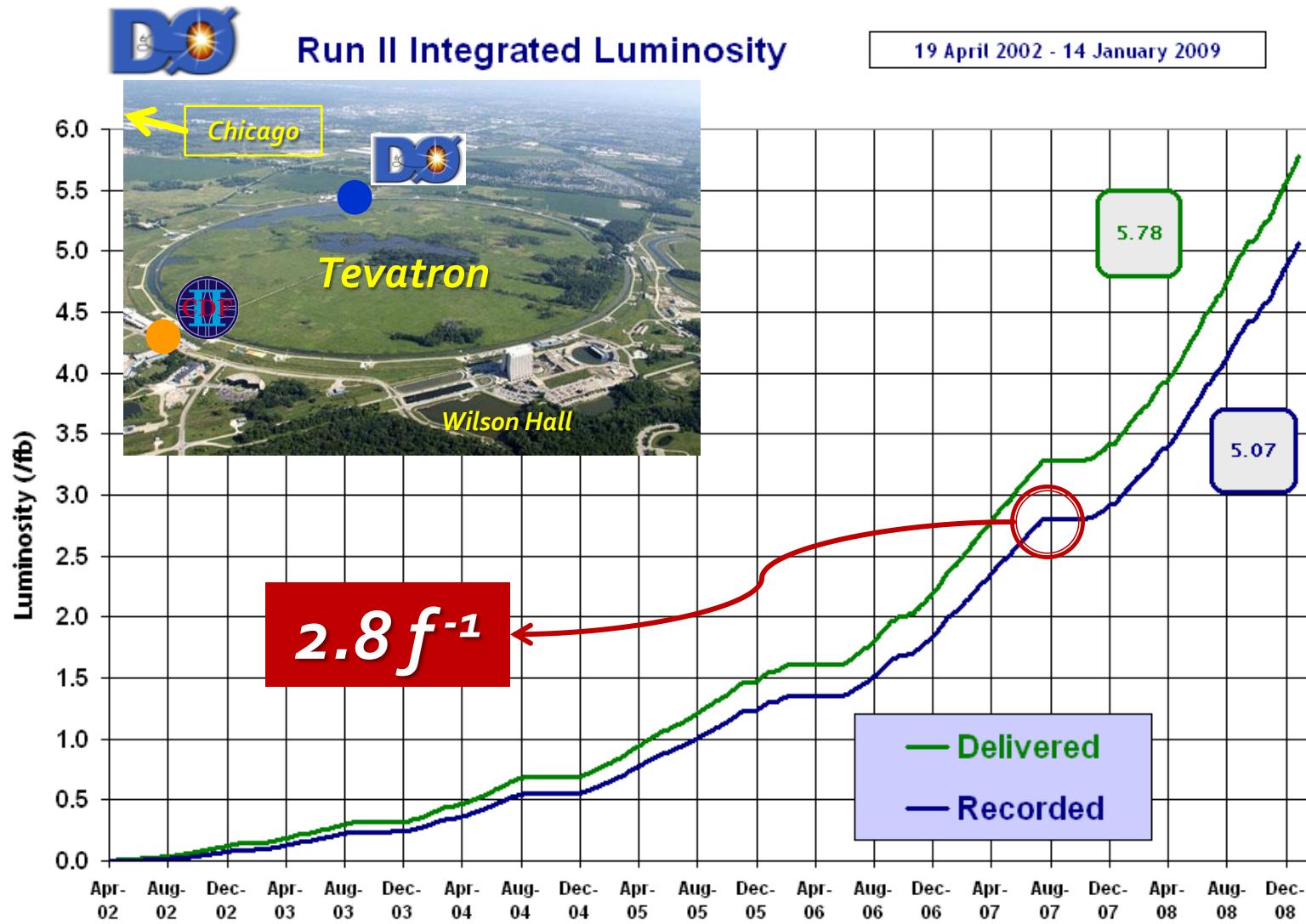


Tevatron & DØ Detector



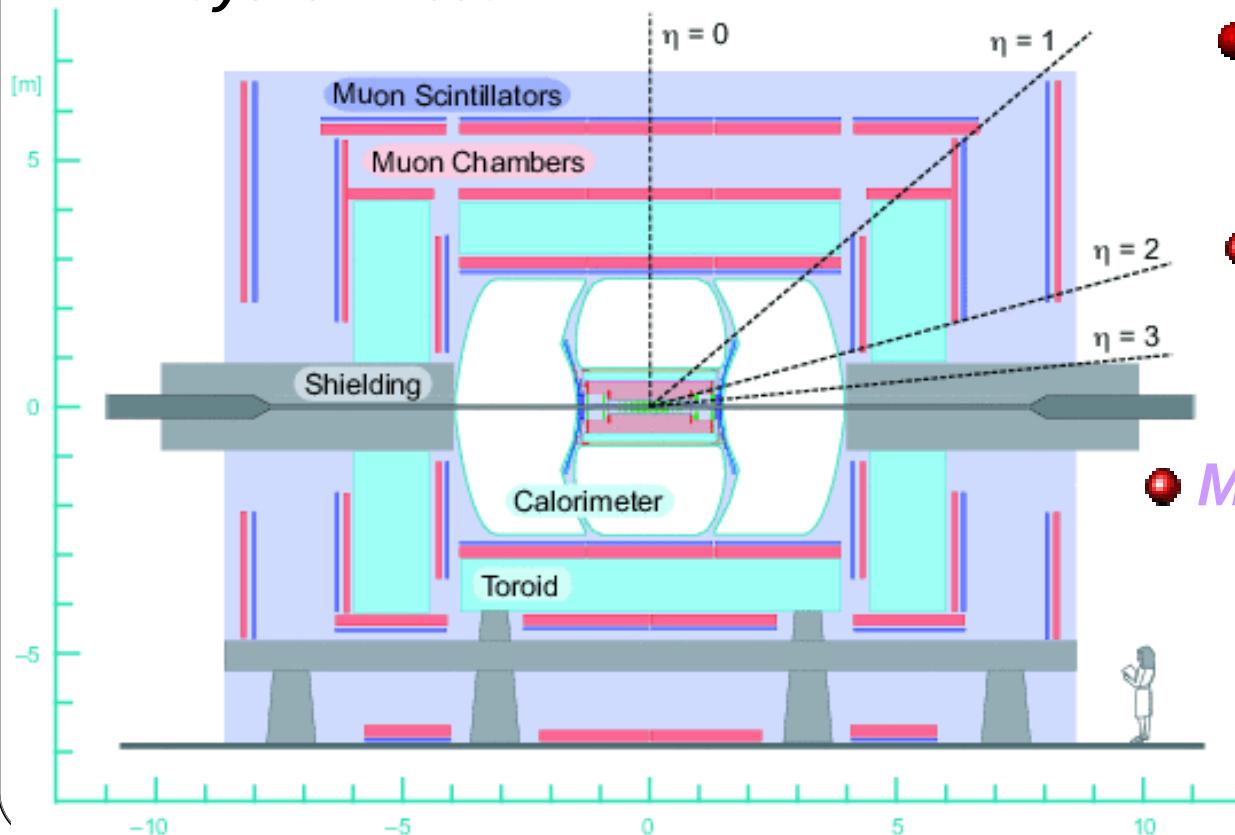


Tevatron



● Tracking system

- Silicon Microstrip Tracker & Central Fiber Tracker
- essential for displaced vertices
- Layer Ø in 2006
- $|\eta| < 3.0$



● Solenoid magnet

- $2 T$

● Calorimeter

- uranium / liquid Ar

● Muon system

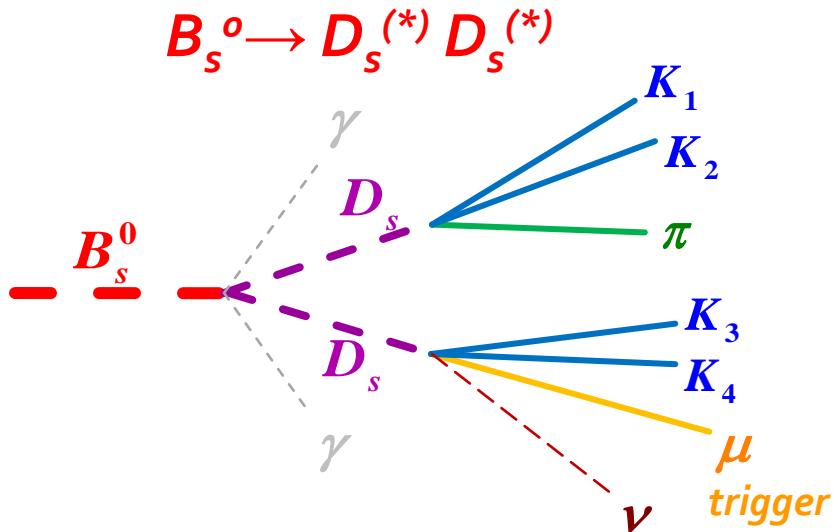
- drift tubes & scintillators
- $1.8 T$ toroid
- excellent muon trigger
- $|\eta| < 2.0$



Analysis Procedure

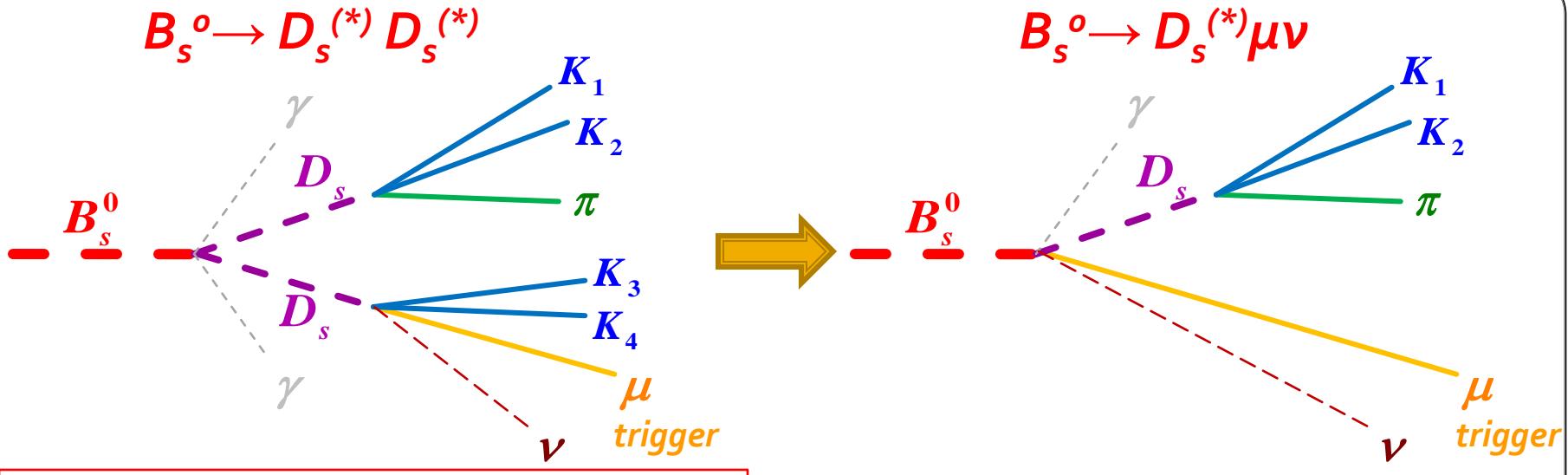


Overall Procedure

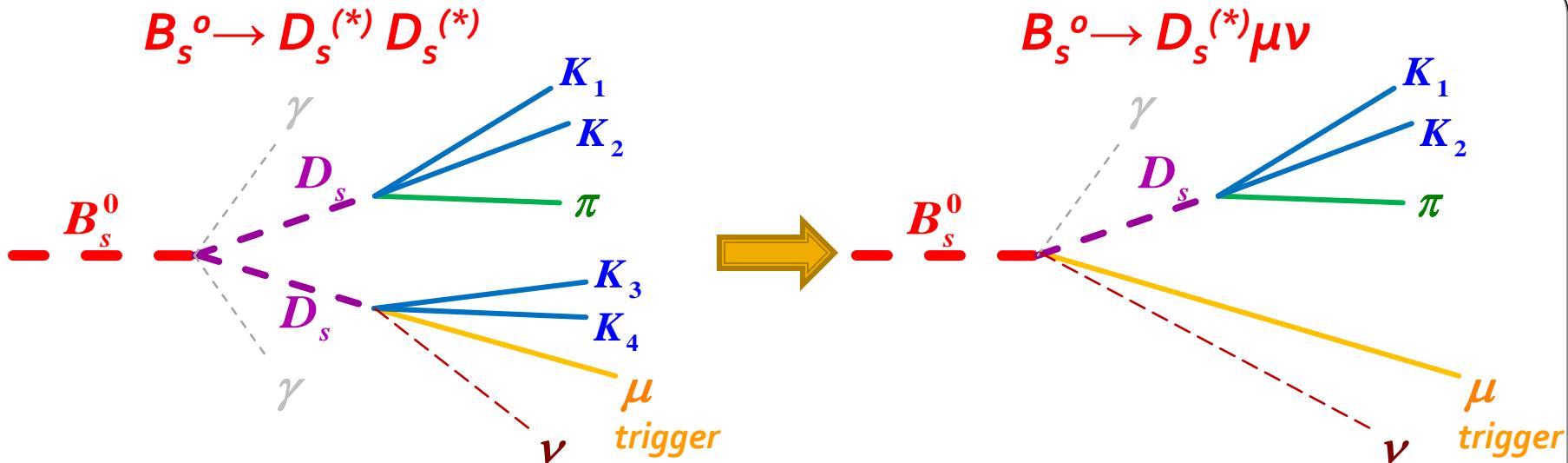


Correlation between two D_s mesons

Overall Procedure



Overall Procedure



Correlation between two D_s mesons

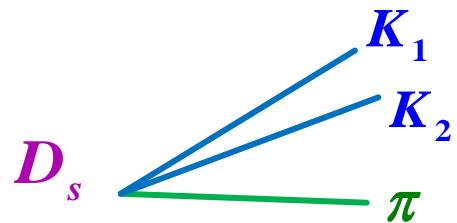
$$\frac{N(B_s \rightarrow D_s^{(*)} D_s^{(*)})}{N(B_s \rightarrow D_s^{(*)} \mu\nu)} = 2R \cdot \frac{\varepsilon(B_s \rightarrow D_s^{(*)} D_s^{(*)})}{\varepsilon(B_s \rightarrow D_s^{(*)} \mu\nu)}$$

$$R \equiv \frac{Br(B_s \rightarrow D_s^{(*)} D_s^{(*)}) \cdot Br(D_s \rightarrow \phi \mu\nu) \cdot Br(\phi \rightarrow K^+ K^-)}{Br(B_s \rightarrow D_s^{(*)} \mu\nu)}$$

(many detector-related systematic effects cancel)



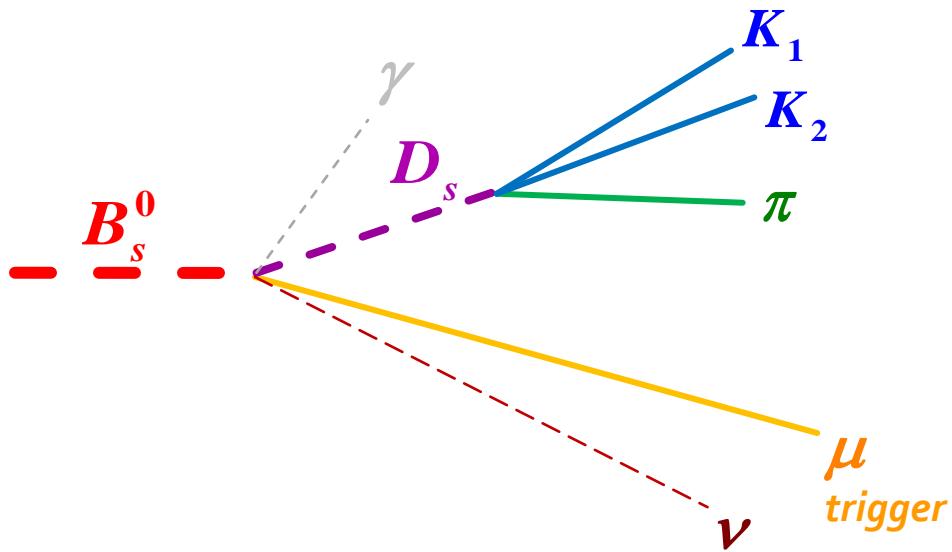
Common Sample ($D_s + \mu$)



μ
trigger

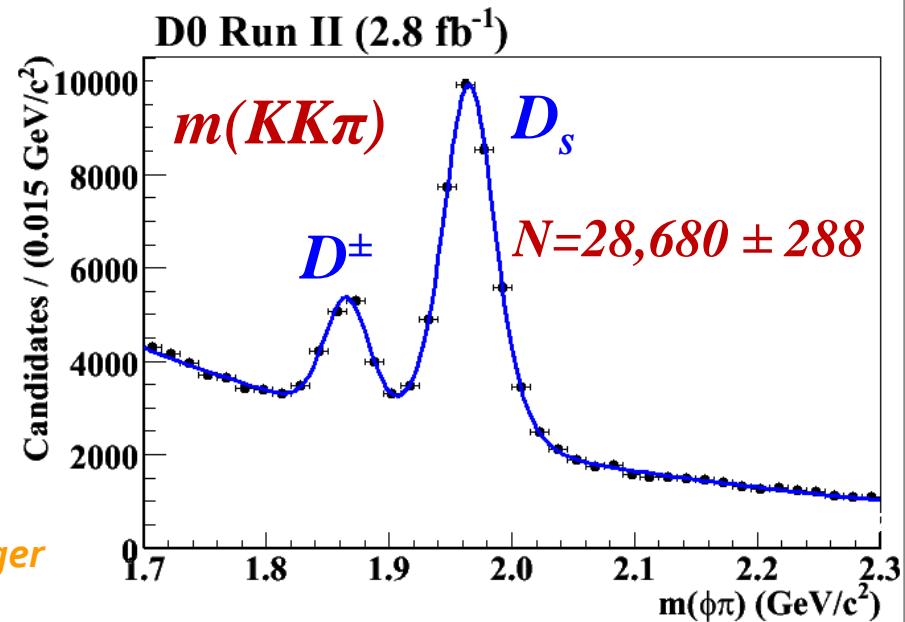
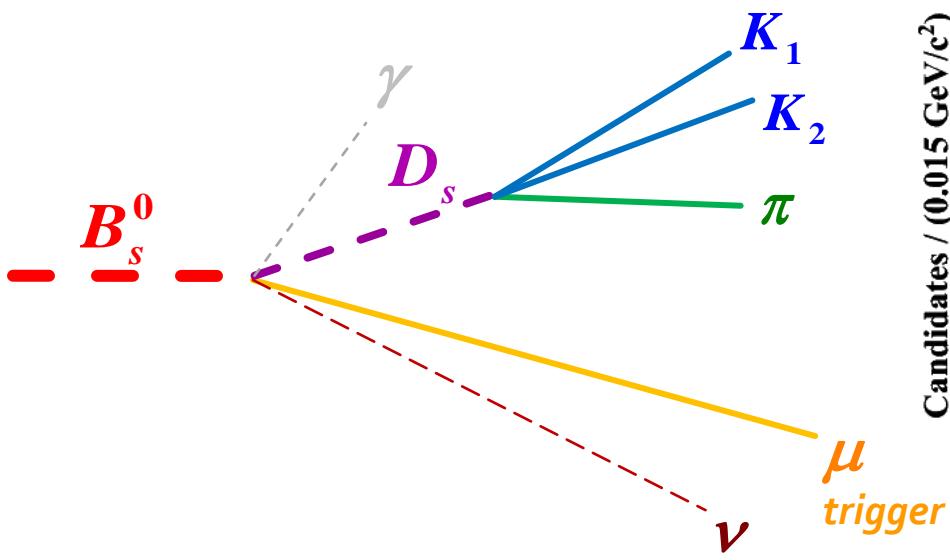


$D_s\mu$ Sample ($B_s^0 \rightarrow D_s^{(*)}\mu\nu, \dots$) - normalization

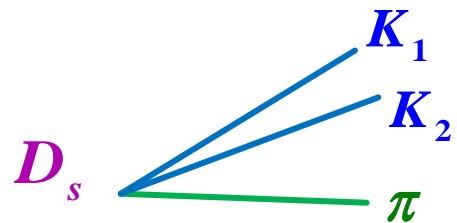


Sampling - $D_s\mu$

$D_s\mu$ Sample ($B_s^0 \rightarrow D_s^{(*)} \mu \nu, \dots$) - normalization



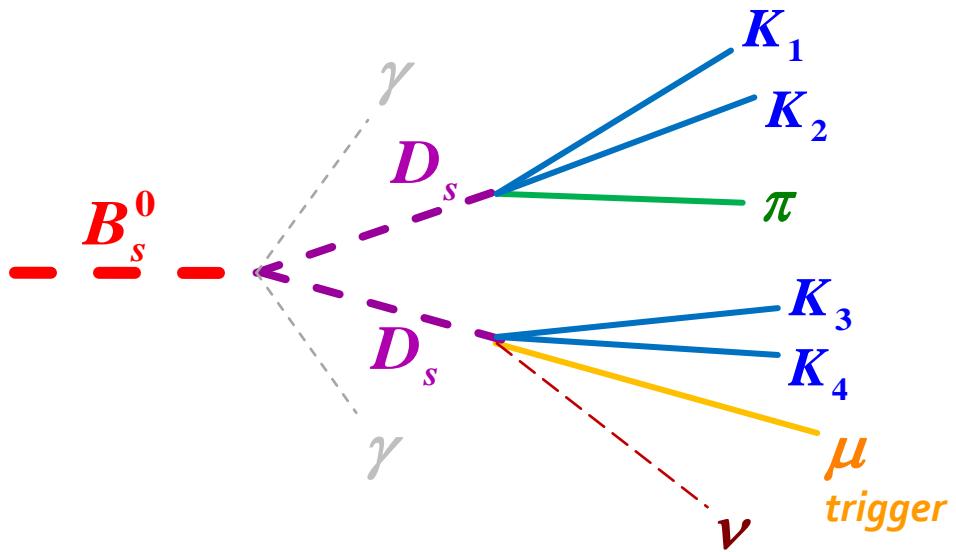
Common Sample ($D_s + \mu$)



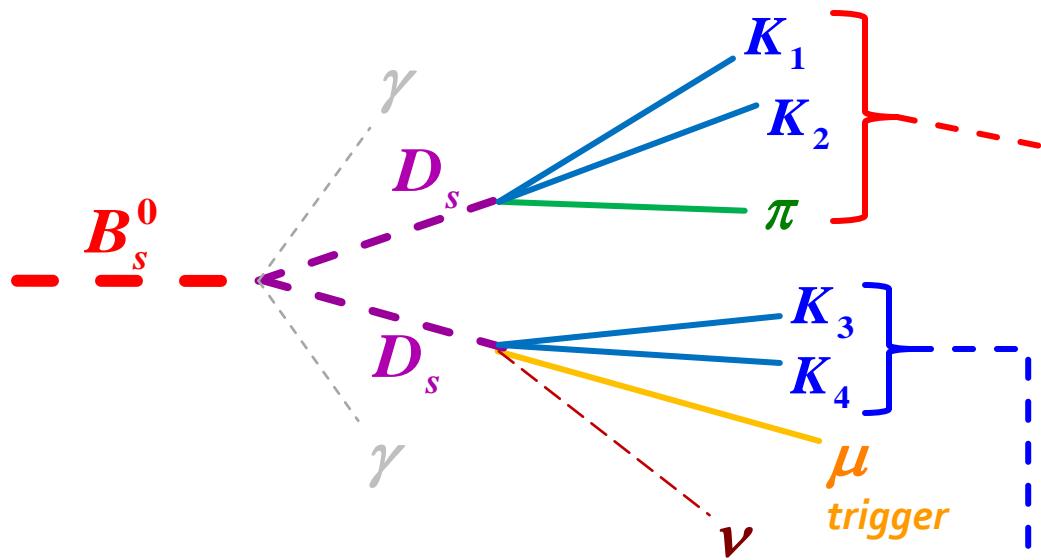
μ
trigger



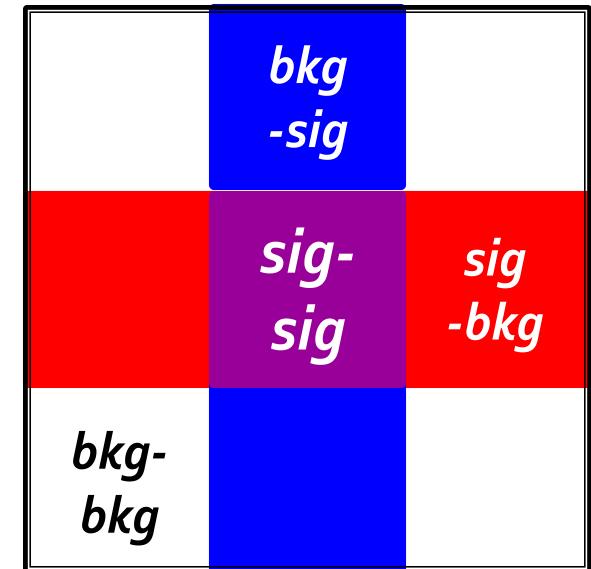
$D_s \varphi \mu$ Sample ($B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}, \dots$) - signal



$D_s \phi \mu$ Sample ($B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}, \dots$) - signal



$m(K_1 K_2 \pi)$ vs. $m(K_3 K_4)$

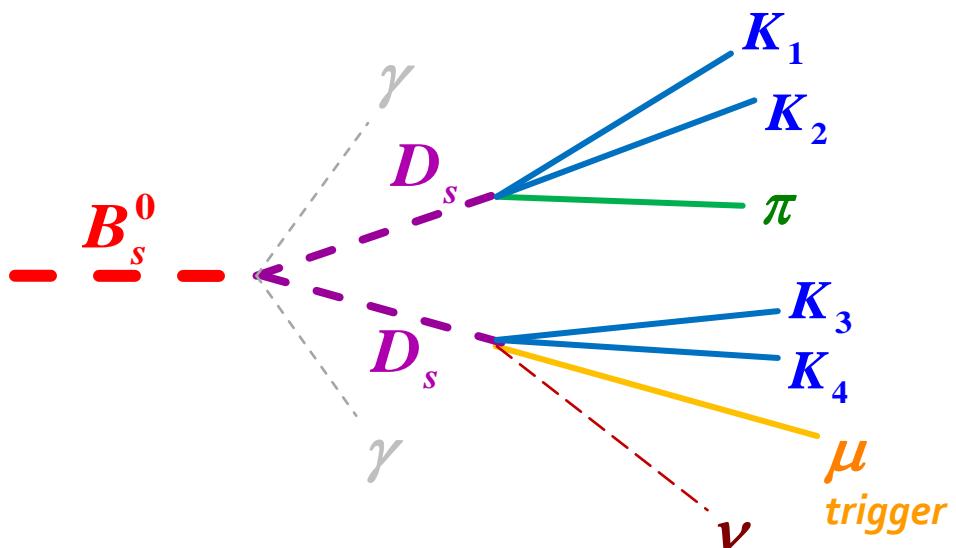


$\rightarrow m(K_3 K_4)$

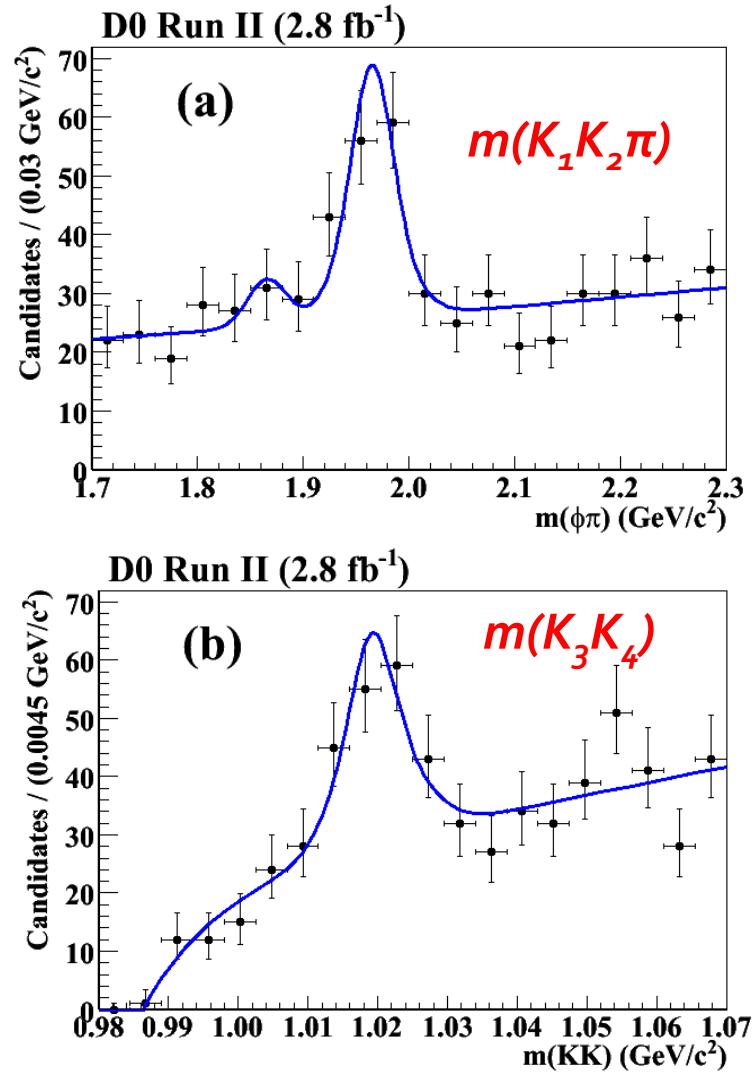
- parameters of the signal models:
determined from $D_s \mu$ sample



$m(K_1 K_2 \pi)$ vs. $m(K_3 K_4)$



$N(\text{correlated}) = 31.0 \pm 9.4$



Background

Physics-suppressed

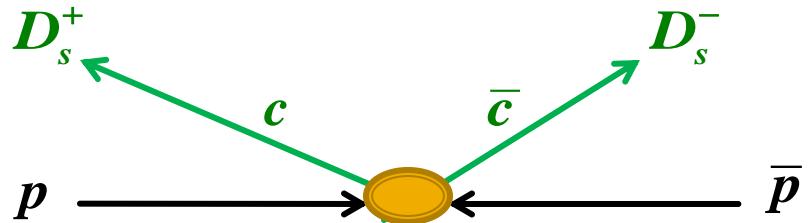
Process	Remark	Recipe	Contrib.
$B_s^0 \rightarrow D_s^{(*)} D_s^{(*)} X$	two gluons required	negligible	$\sim 0\%$

Kinematics-suppressed → Sample composition

Process	Remark	Recipe	Contrib.
$B^{\pm,0} \rightarrow D_s^{(*)} D_s^{(*)} K X$	low mass ($D_s \varphi \mu$)	$m(D_s \varphi \mu) > 4.3 \text{ GeV}$	$5 \pm 2\%$
$B_s^0 \rightarrow D_s^{(*)} \mu \nu \varphi$	high mass ($\varphi \mu$)	$m(\varphi \mu) > 1.85 \text{ GeV}$	$0 \pm 3\%$

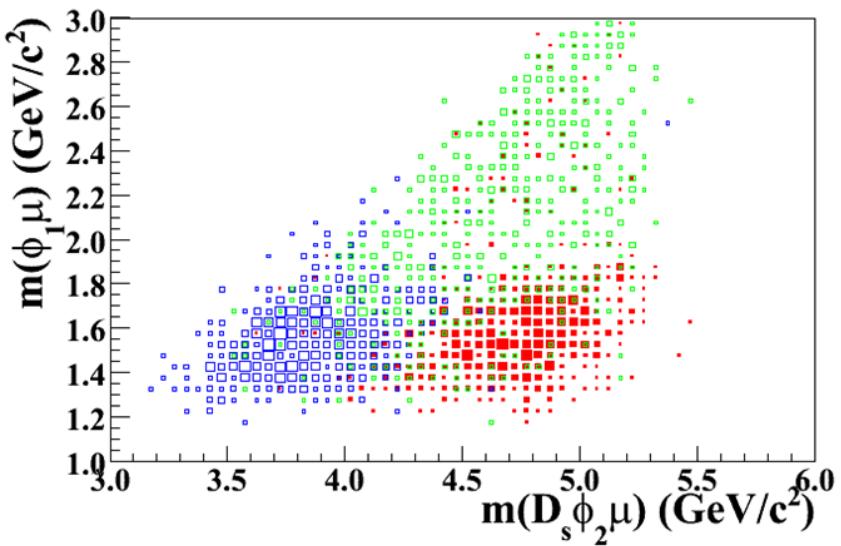
$c\bar{c}$ contamination

$f_{cc}(D_s \mu \text{ sample}) = 10.3 \pm 2.5\%$
 from lifetime distribution for
 Δm_s analysis



Process	Comment	Recipe	Contrib.
$c\bar{c} \rightarrow D_s^{(*)} \varphi \mu X$	short decay length	lifetime cut	$2 \pm 1\%$



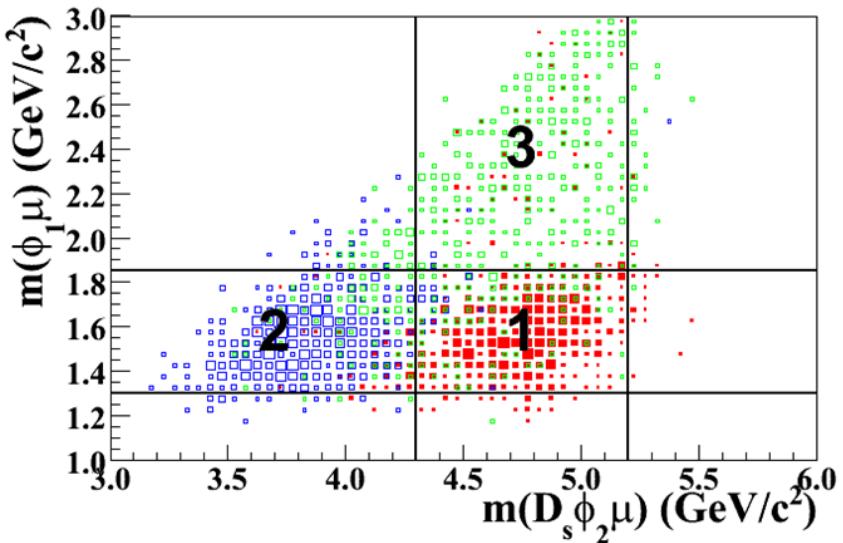


a: $B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}$

b: $B^{\pm,0} \rightarrow D_s^{(*)} D_s^{(*)} K X$

c: $B_s^0 \rightarrow D_s^{(*)} \mu\nu\varphi$





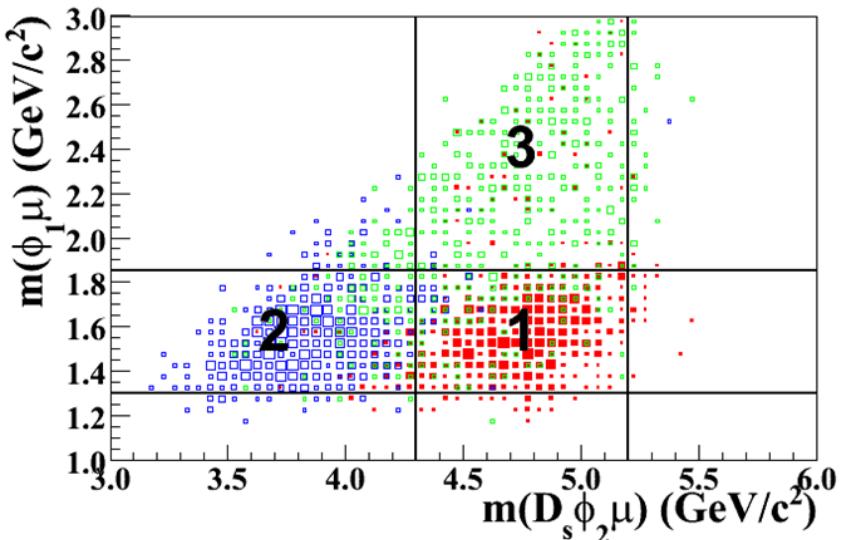
M_i : total # of events for channel i (data)
 n_j : total # of events in region j (fitting)
 $f_{i,j}$: frac. for channel i in region j (MC)

$$\Rightarrow \begin{pmatrix} f_{a,1} & f_{b,1} & f_{c,1} \\ f_{a,2} & f_{b,2} & f_{c,2} \\ f_{a,3} & f_{b,3} & f_{c,3} \end{pmatrix} \begin{pmatrix} M_a \\ M_b \\ M_c \end{pmatrix} = \begin{pmatrix} n_1 \\ n_2 \\ n_3 \end{pmatrix}$$

a: $B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}$

b: $B^{\pm,0} \rightarrow D_s^{(*)} D_s^{(*)} K X$

c: $B_s^0 \rightarrow D_s^{(*)} \mu \nu \varphi$



a: $B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}$

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$$N(D_s^{(*)} D_s^{(*)}) = N(\text{correlated}) \cdot F_{a,1}$$

$$\text{where, } F_{a,1} = \frac{f_{a,1} \cdot M_a}{\sum_i f_{i,1} \cdot M_i}$$

Signal yield: $N(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}) = 26.6 \pm 8.4$

— $N(\text{correlated}) = 31.0 \pm 9.4$ —



Significance



Significance for maximum likelihood fit

$$- S = \text{sqrt} \{ -2 \ln(L_o / L_{max}) \}$$

L_o : likelihood value returned by the fit with the bkg. only hypothesis

L_{max} : likelihood value returned by the nominal (bkg.+sig. hypothesis) fit

- correlated background is considered and systematic uncertainties are included in calculation

smear N (correl. bkg) using Gamma distribution

smear fitting parameters by $\pm 1\sigma$ using Gaussian distributions

repeat the fit 10,000 times to calculate significance

average the individual significances

$$S = \frac{\sum_i S_i}{N} \quad (N = 10,000)$$

Significance = 3.2 σ



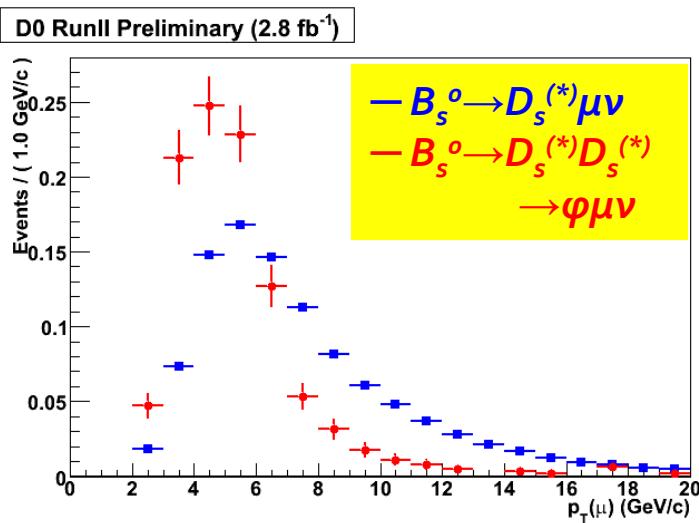


Single Muon Trigger Efficiency

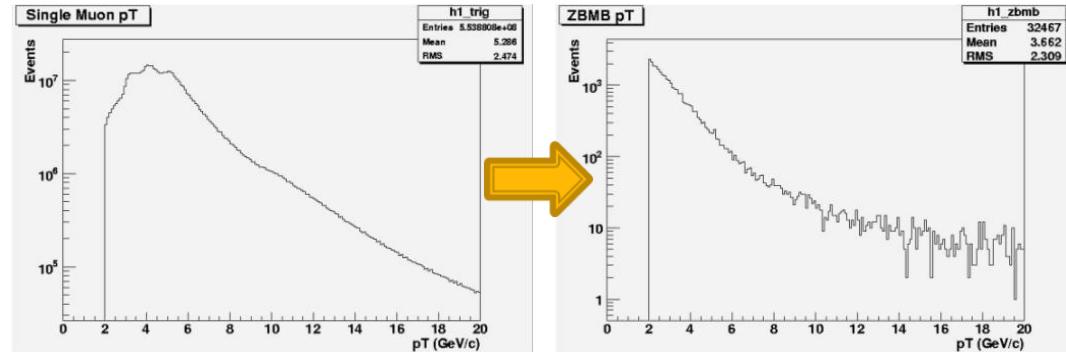


Complicated to correct for the difference in p_T distributions from different decay processes
 - ex) $b \rightarrow \mu$ vs $b \rightarrow c \rightarrow \mu$

Understanding trigger effect is essential for low p_T physics



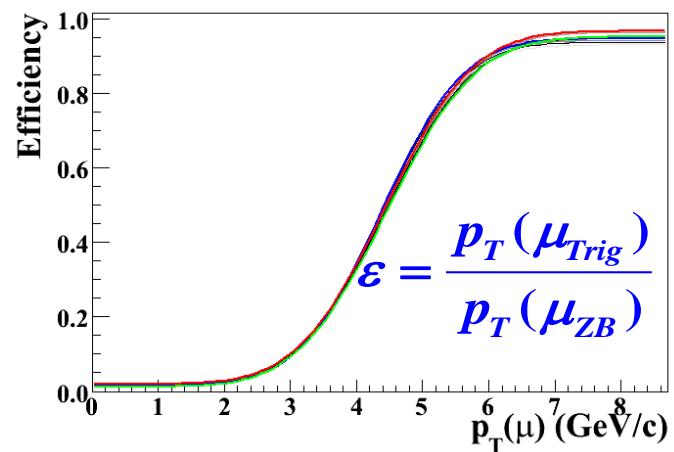
Inclusive single muon sample



triggered muon p_T

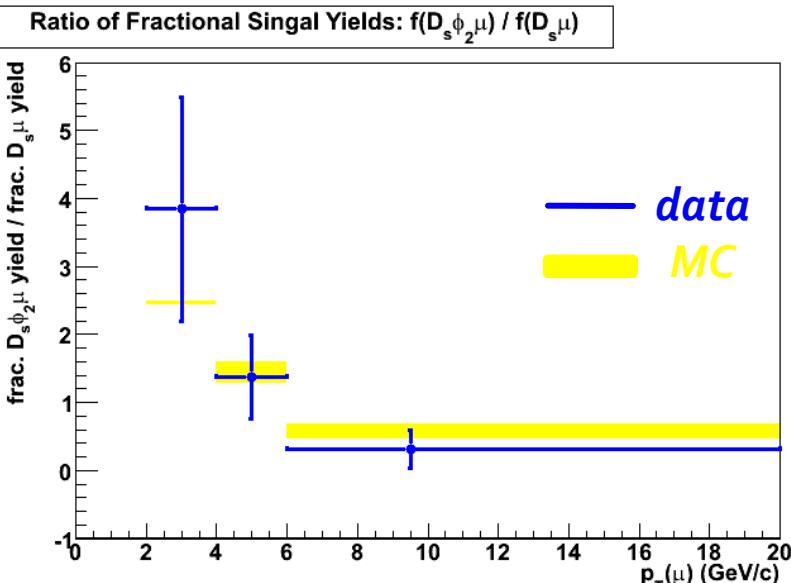
unbiased muon p_T

Universal Trigger Turn-on Curve



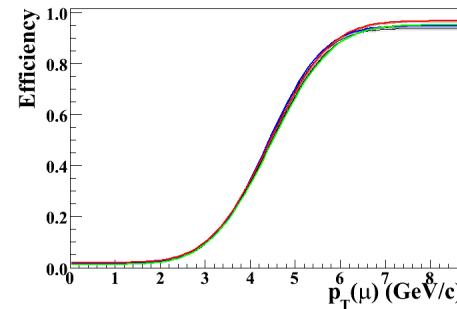
Two trigger models

- one w/ turn-on (**weighted**)
- one w/o turn-on (**un-weighted**)

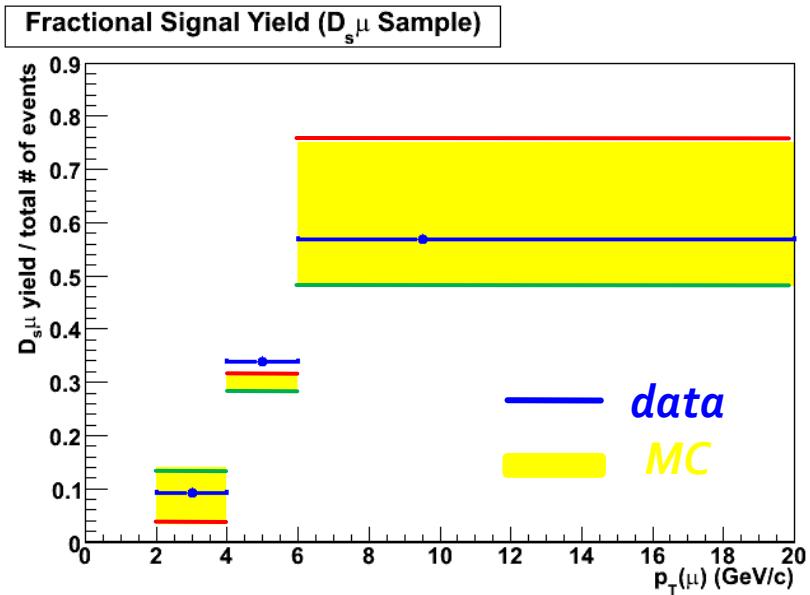


Ratio of signal yields:

$$f(D_s \phi \mu) / f(D_s \mu)$$



Yes vs. No



signal yields of $D_s \mu$ sample





Systematic Uncertainties





Systematic Uncertainties

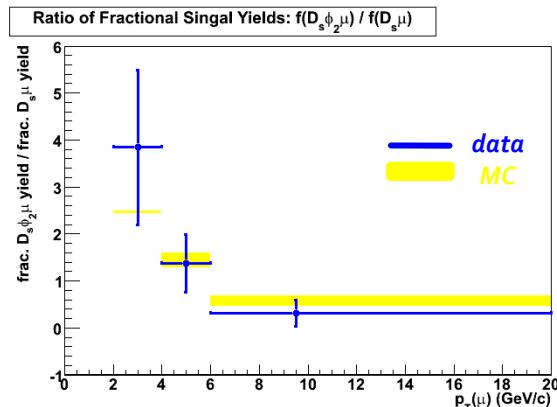


Source	Uncertainty
$Br(B_s^0 \rightarrow D_s^{(*)} \mu v)$	0.0061
$Br(D_s \rightarrow \varphi \pi) \cdot Br(\varphi \rightarrow KK)$	0.0032
$Br(D_s \rightarrow \varphi \mu v) / Br(D_s \rightarrow \varphi \pi)$	0.0026
$\epsilon(D_s^{(*)} D_s^{(*)}) / \epsilon(D_s^{(*)} \mu v)$	0.0065
$N(D_s^{(*)} D_s^{(*)})$: Matrix	0.0036
fitting procedure	0.0021
ccbar	0.0013
$f(B_s^0 \rightarrow D_s^{(*)} \mu v)$	0.0004
$N(D_s \mu)$	0.0004
Total	0.0108
Statistical Uncertainty	0.0104

Poor Input branching ratios

- largest source (> 45%)
- room for further improvement

Reconstruction efficiency (~35%)



BKG Estimation (Matrix method)

ccbar contamination ~ 1%





Result & Conclusion





Result



Branching ratio

- $Br(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}) = 0.035 \pm 0.010 \text{ (stat)} \pm 0.011 \text{ (syst)}$
- significance: 3.2σ Evidence!!!

$$\frac{N(B_s \rightarrow D_s^{(*)} D_s^{(*)})}{N(B_s \rightarrow D_s^{(*)} \mu\nu)} = 2R \cdot \frac{\varepsilon(B_s \rightarrow D_s^{(*)} D_s^{(*)})}{\varepsilon(B_s \rightarrow D_s^{(*)} \mu\nu)}$$

$$R \equiv \frac{Br(B_s \rightarrow D_s^{(*)} D_s^{(*)}) \cdot Br(D_s \rightarrow \phi \mu\nu) \cdot Br(\phi \rightarrow K^+ K^-)}{Br(B_s \rightarrow D_s^{(*)} \mu\nu)}$$



Branching ratio

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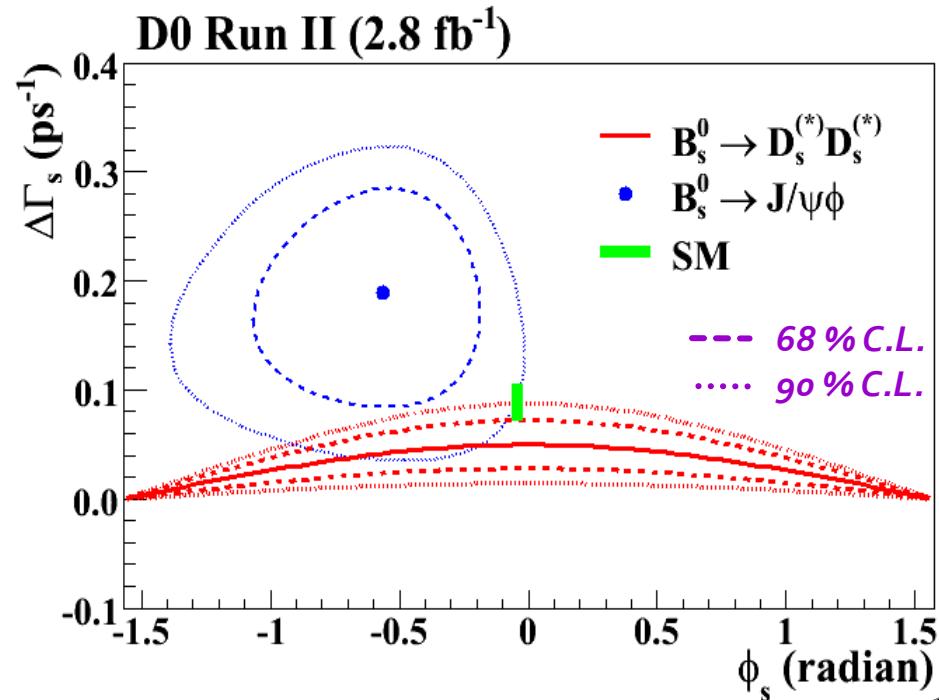
Lifetime difference and CPV information

- under theoretical assumptions

$$2Br(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}) \simeq \Delta\Gamma_s^{CP} \left(\frac{1 + \cos\phi_s}{2\Gamma_L} + \frac{1 - \cos\phi_s}{2\Gamma_H} \right)$$

$$\Delta\Gamma_s = \Gamma_L - \Gamma_H, \quad \Gamma_s = \frac{\Gamma_L + \Gamma_H}{2}$$

$$\Delta\Gamma_s = \Delta\Gamma_s^{CP} \cos\phi_s$$



Branching ratio

- $Br(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}) = 0.035 \pm 0.010 \text{ (stat)} \pm 0.011 \text{ (syst)}$
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Lifetime difference and CPV information

- under theoretical assumptions
- in the SM framework

$$\frac{\Delta\Gamma_s^{SM}}{\Gamma_s} \simeq \frac{2Br(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)})}{1 - Br(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)})} = 0.072 \pm 0.021 \text{ (stat)} \pm 0.022 \text{ (syst)}$$

	$Br(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)})$	$\Delta\Gamma_s / \Gamma_s$
ALEPH (2000)	$0.077 \pm 0.034 {}^{+0.038}_{-0.026}$	$0.167 \pm 0.070 {}^{+0.079}_{-0.053}$
Do (2007, $1.3 fb^{-1}$)	$0.039 {}^{+0.019}_{-0.017} {}^{+0.016}_{-0.015}$	$0.081 {}^{+0.039}_{-0.035} {}^{+0.033}_{-0.030}$
WA (end of 2007)	0.046 ± 0.022	0.096 ± 0.048
Theory	0.048 ± 0.009	0.127 ± 0.024





Conclusion



Study of $B_s^0 \rightarrow D_s^{()} D_s^{(*)}$ using 2.8 fb^{-1}*

- $\text{Br}(B_s^0 \rightarrow D_s^{(*)} D_s^{(*)}) = 0.035 \pm 0.010 \text{ (stat)} \pm 0.011 \text{ (syst)}$

CPV information and lifetime difference

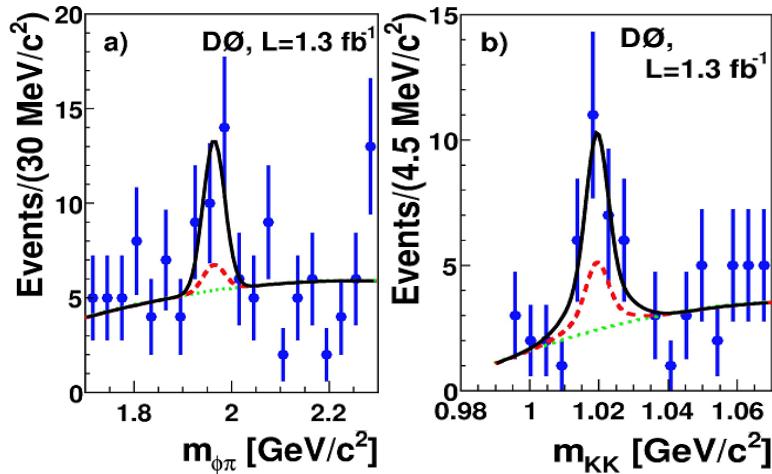
- under various theoretical assumptions
- $\Delta\Gamma_s^{SM}/\Gamma_s = 0.072 \pm 0.021 \text{ (stat)} \pm 0.022 \text{ (syst)}$
- consistent with experiment and theory

Powerful constraint on mixing and CPV in B_s^0 system

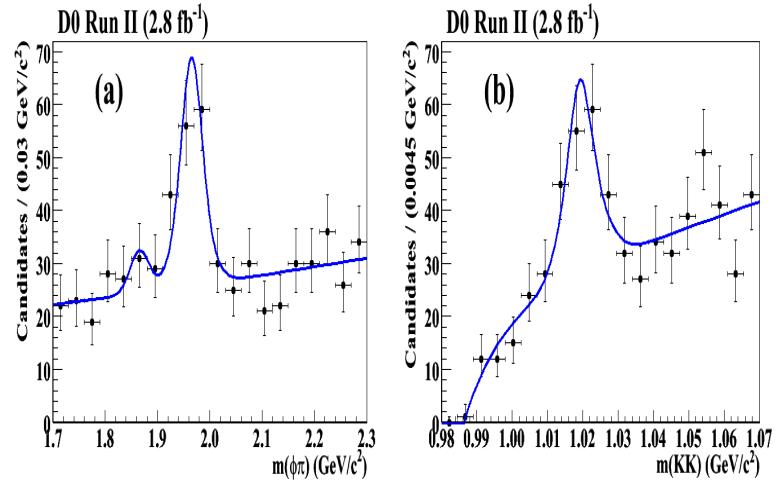
- significant improvement of scientific understanding of CPV
- theoretical errors controlled and CP structure disentangled

First single experimental measurement for $\Delta\Gamma_s \neq 0$ at $> 3 \sigma$





VS.



- *Sample selection efficiency - Likelihood Ratio Variable*
 - 13.4 ± 6.3 vs. 15.7 ± 7.2 (Run IIa, $1.3 f^{-1}$)
- *Background estimation - Matrix method*
- *Trigger modeling – trigger turn-on curve*
- *Significance calculation*
- *First interpretation of the measurement*





To Public



- *Flavor Physics and CP violation (FPCP) – May 2008, Taipei*
'DØ Hot Topics'
- *Result of Week (Fermilab Today) – May 2008, Fermilab*
'When less is more'
- *Fermilab User's Meeting – June 2008, Fermilab*
invited graduate student talk
- *International Conference on High Energy Physics (ICHEP) – July 2008, Philadelphia*
- *Submitted to Phys. Rev. Lett. (arXiv:0811.2173) – November, 2008*

Report of Referee A -- LY11287/Abazov

This paper is well written and the subject is very interesting. The evidence for a width difference in B_s decays is probing new territory. The paper does a good job of relating the experimental data and theoretical implications.

My only suggestion concerns the paragraph discussing the correlated production. It needs an introductory sentence for the non expert, explaining why the reader cares about the correlation.

Excellent paper.





To Public



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Backup Slides

*SungWoo YOUN
Northwestern University*

*Interview for Postdoctoral Position @ FNAL
(01/20/09)*



Likelihood Ratio Variable

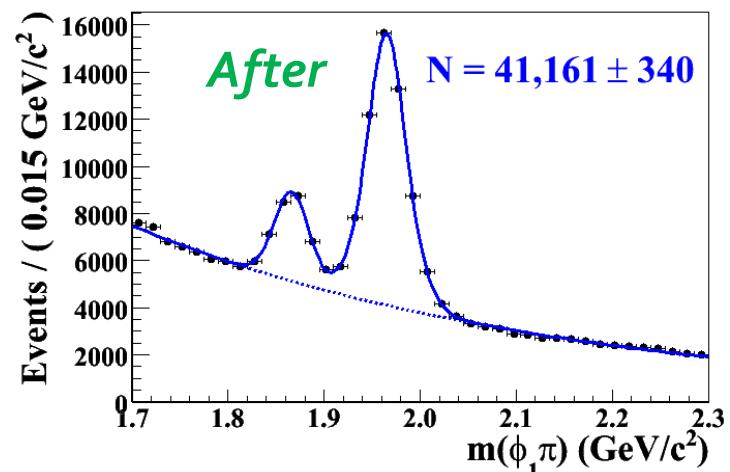
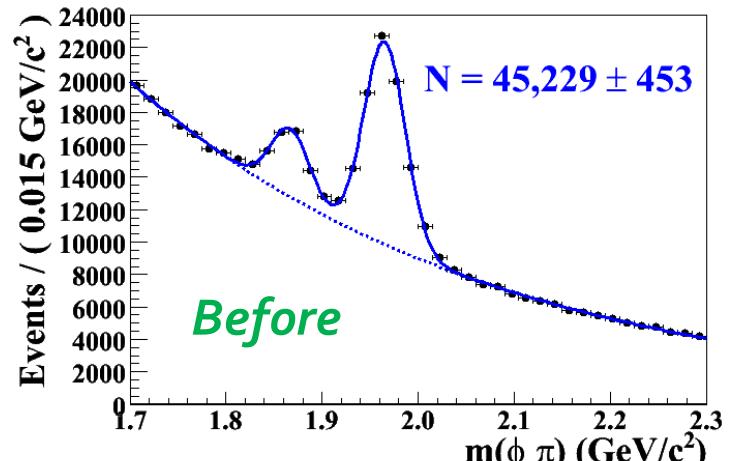


$$Y = \prod_i y_i; \quad y_i = \frac{PDF_{bkg}(x_i)}{PDF_{sgl}(x_i)}$$

(x_i : discriminating variable)

$$\text{maximal } S / \sqrt{S + B}$$

$D_s\mu$ Sample	$D_s\phi\mu$ Sample
<i>isolation</i> (B_s)	<i>isolation</i> (B_s)
$\cos(\theta_{hel})$	$\cos(\theta_{hel})$
$p_T(K_1 K_2)$	$p_T(K_1 K_2)$
$m(B_s)$	$m(B_s)$
$\chi_{vtx}^2(D_s)$	$m(K_3 K_4) - m(K_1 K_2)$
$m(K_1 K_2)$	$p_T(\varphi_2) - p_T(\varphi_1)$
	$p_T(D_{s,2}) - p_T(D_{s,1})$



SIGNAL CLEAR-UP





Default

